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(54) Adaptive scanning technique for wavelet video coding

(57) A video coding method using wavelet with an adaptive scanning method has such main steps of:

subjecting the input video signal to a horizontal and a vertical wavelet decomposition to obtain the base, horizontal, vertical and diagonal band of wavelet coefficients;
recursively subjecting the resulting base band to further wavelet decomposition to obtain lower layers of base, horizontal, vertical and diagonal bands of wavelet coefficients;
grouping the co-sited coefficients from the different layers of horizontal, vertical and diagonal bands into a plurality of horizontal, vertical and diagonal macro-bands, respectively;
applying an adaptive quantization to quantize the above coefficients in the said horizontal, vertical and diagonal macro-bands, respectively;
adaptively scanning and differentially coding the quantized coefficients in the said macro-bands into a plurality of one dimensional arrays, using a technique depending on orientation of the macro-bands and the distribution of the coefficients, and
applying an entropy coding method to code each of the said arrays.

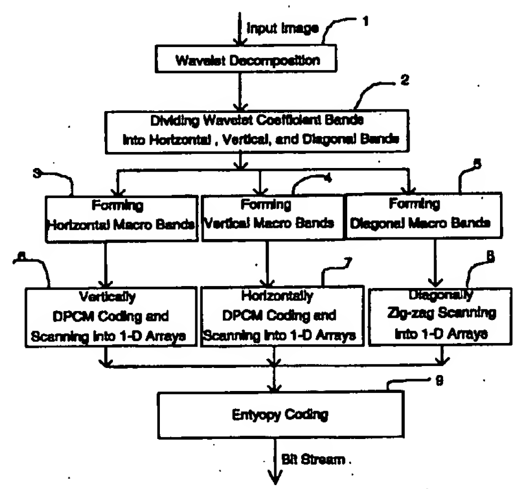

Figure 5 General Diagram for H_Band/V_Band/D_Band Scan

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Description

BACKGROUND OF THE INVENTION

1. Industrial Fields of the Invention

This invention relates to wavelet decomposition, especially to wavelet based video coding.

2. Related art of the Invention

Besides DCT (Digital Cosine Transform) used in video coding, recently wavelet transform has been widely studied in video signal coding, since wavelet decomposition has spatio-frequency localization properties.

Wavelet transform is an alternative representation of image data. It decomposes an input raster image hierarchically in the vertical and horizontal direction, and forms many different multiresolution bands.

Figure 1 illustrates an example, wavelet decomposition process, where an input image is decomposed into 13-band of wavelet coefficient, after 4 times of decomposition.

The three B4 bands are obtained from the first horizontal/vertical wavelet decomposition; the three B3 bands are obtained from the second decomposition; and so on. The lower bands B1, B2, and B3 contain much of the information of the original image, and the higher band B4 contributes detailed information to the original image.

Figure 2 shows the real wavelet coefficients for Carphone Sequence, which is decomposed once by wavelet transform. It can be seen that there are some non-zero wavelet coefficients vertically distributed in the horizontal band , Hh, because of vertical edges in the original image, and some non-zero wavelet coefficients horizontally distributed in the vertical band, Hv, because of horizontal edges in the original image.

It has been known that if those non-zero wavelet coefficients in Figure 2 could be represented and coded by using less bits, then the efficiency of the wavelet compression would be high.

In the paper "Wavelet Coefficients Scanning Methods for Video Coding", three scanning methods for wavelet coefficients were presented. One of them is called H_Band/V_Band/D_Band Scan, which is the best scan among the three scanning methods.

Figure 3 illustrates the scanning mechanism for H_Band/V_Band/D_Band Scan.

Firstly wavelet coefficients are diveided into three kinds of bands:horizontal band, vertical band, and Diagonal band. Within the horizontal bands, B1h, B2h, B3h, and B4h, different number of wavelet coefficients are taken from different horizontal bands, one from B1h, 2x2 from B2h, 4x4 from B3h, 8x8 from B4h, and then they are grouped into a macro band with total number of 85 items. Finally the macro band is quantized and Huffman VLC coded.

Figure 4 shows an example of three macro bands to be formed from horizontal bands, vertical bands, and diagonal bands, respectively. In the same paper "Wavelet Coefficients Scanning Methods for Video Coding", one dimension array will be further formed just by using normal raster scan no matter what band it is from. But it can be seen from Figure 4 that in the horizontal band, there are a lot of cases where non-zero wavelet coefficients are vertically distributed, and inversely in the vertical band, there are a lot of cases where non-zero wavelet coefficients are horizontally distributed.

So if the situation could be considered, scanning wavelet coefficients vertically in horizontal bands and scanning wavelet coefficients horizontally in vertical bands, instead of raster scan, then the coding efficiency would be increased further.

In the same time, since a run-length Huffman VLC like entropy encoder will be applied to the array here, if non-zero wavelet coefficients in the array appear as the front of the array as much as possible, as well as to be small as much as possible, then less bits will be consumed.

The invention here is going to propose an adaptive scanning and DPCM process for the H_Band/V_Band/D_Band Scan to improve its coding efficiency further, and the concept is also applicable to the similar cases where wavelet or subband decomposition is used and non-zero coefficients appear vertically in horizontal bands and horizontally in vertical bands.

Wavelet coding is composed of Wavelet Decomposition, Scanning, Quantizaition, as well as entropy coding. Besides choosing a bettter wavelet transform, scanning and quantising wavelet coefficients efficient ly is also very important.

Edge information in an original image is often corresponding to non-zero wavelet coefficients after wavelet decomposition, and normally these coefficients are vertically distributed in horizontal bands and horizontally distributed in vertival bands. The invention is trying to make use of the phenomena to scan wavelet coefficients adaptively, so as to improve the coding efficiency of wavelet.

Further, it is shown that non-zero wavelet coefficients are distributed in different vertical line for different images, taken horizontal macro band as an example shown in Figure 4. In order to use less bits to code them by Huffman VLC like entropy coder, those non-zero coefficients are needed to scan and put in the front of a 1-Dimension array as much as possible.

There are a lot of cases where wavelet coefficients in the same vertical line for horizontal band have the same value, at least have the same sign. So one dimension of DPCM coding could be used here for reducing the redundancy between neighbour coefficients.

SUMMARY OF THE INVENTION

In this invention wavelet coefficients are scanned vertically for a horizontal band, horizontally scanned for

a vertical band, and zig-zag for a diagonal band.

Non-zero wavelet coefficients are scanned and put in the front of an array as much as possible by searching the first vertical line with non-zero coefficients in its first value in horizontal bands, and the first horizontal line with non-zero coefficients in its first value in vertical bands.

DPCM coding is done vertical within a vertical line for a horizontal band, and horizontally done within a horizontal line for a vertical band.

Hereinafter the operation of the present invention is described

An input image is decomposed by wavelet transform, quantized by using different quantization step. H_Band/V_Band/D_Band scan is applied here.

In the meantime, for horizontal bands each of 1-D array is obtain ed after using one dimensional DPCM coding within a vertival line, searcing the first vertical line with non-zero coefficients in its first value, and scanning all the coefficients vertically, and for vertical bands each of 1-D array is obtained after using one dimensional DPCM within a horizontal line , searching the first horizontal line with non-zero coefficients in its first value, and scanning all the coefficients horizontally.

For diagonal bands,a conventional zig-zag scan is applied directly.

Then Huffman VLC coding can be used to code each of array obtain ed from above-mentioned method.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows wavelet decomposion with 13 bands after 4 times of decomposition.

Figure 2 is an example of the distribution of wavelet coefficients for carphone sequence.

Figure 3 is an illustration of H_Band/V_Band/D_Band Scan.

Figure 4 shows a real case of horizontal macro band, vertical macro band, and diagonal macro band for Carphone Sequence.

Figure 5 is a general diagram of H_Band/V_Band/D_Band with DPCM & Adaprive Scanning.

Figure 6 shows the detai of DPCM & Adaptive Scanning.

Figure 7 is an explanation for Adaptive Scanning technique.

Figure 8 is an encoder of Wavelet Coding by using HVDS with DPCM & Adaptive Scanning.

PREFERRED EMBODIMENTS

The preferred embodiment of the present invention would be best explained by following Figures 5, 6, 7, and 8.

Figure 5 is a general diagram for H_Band/V_Band/D_Band scan, where wavelet transform in unit 1 is applied to an input image, in unit 2 wavelet coefficients for whole frame are divided into horizontal band, vertical band and diagonal band. Then in unit 3 horizontal macro bands will be obtained by taking one coefficient from B1h, 2x2 coefficients from B2h, 4x4 coefficients from B3h, and 8x8 codfficients from B4h, as shown in Figure 3 for horizontal bands; in unit 4 vertical macro bands will be obtained by taking one coefficients from B1v, 2x2 from B2v, 4x4 from B3v, and 8x8 from B4v for vertical bands; in unit 5 diagonal macro bands will be obtained by taking one coefficients from B1d, 2x2 from B2d, 4x4 from B3d, and 8x8 from B4d for diagonal bands.

In units 6, 7 and 8 many 1-D arrays will be formed from the unit 3, unit 4, and unit 5, respectively, by use of the current DPCM & Adaptive scan, which will be explained in Figure 6 in detail.

In unit 9 an entropy coding is applied to code each of 1-D array formed in the units 6, 7, and 8.

The detailed procedure is shown in Figure 6 and 7, and in Figure 6 horizontal bands are taken as an example.

As shown in Figure 6, in the unit 10 1-D DPCM is applied between neighbour coefficients within the same vertical line for a horizontal band, for example 4x4, or 8x8. Then in the unit 11 the first vertical line with non-zero coefficients in its first value will be searched, shown in Figure 7.

Taking 8x8 as an example, shown in Figure 7(a), searching is done along the first horizontal line until the first non-zero coefficient is found, i. e., the coefficient of "3" for Horizontal Macro Band, then in the unit 12 just by starting from that coefficient, scanning will be done vertically for that line, followed by next vertical line, formed the order of a, b, c, d, e, f, g, h, as shown in Figure 7(a).

Figure 7(a) is forward adaptive scanning method, and Figure 7(b) is continuous adaptive scanning method.

In Figure 8 it is shown that H_Band/V_Band/D_Band Scan (also call ed HVDS) with DPCM & Adaptive scanning is used in an encoder.

As shown in Figure 8, an input frame is input into Block Sampling in the unit 13, and subjected to Motion Estimation in the unit 15, and motion Compensation in the unit 16. In the unit 14 Reference Frame Memory stores previous frame for motion estimation.

Wavelet Decomposition is done in the unit of 17 for original image, as well as for motion compensated image from the unit of 16.

In the unit of 18, H_Band/V_Band/D_Band Scan is applie to wavelet coefficients from the unit of 17, then an Adaprive Quantization in the unit of 19 is used here, which is adjusted by the unit of 22, Rate-Controller.

In the unit of 20 Rearrangement by DPCM Coding&Adaptive Scanning is done for the coefficients quantized in the unit of 19.

VLC and Huffman Coding is done in the unit of 21, and the coded bitstream is output from the unit of 21.

An inverse process:Inverse Quantization, Wavelet Composition, are shown in the unit of 23 and 24, respectively. In the unit of 25 Local Decoded Frame

Memory is used to store local decoded images for motion compensation.

The invention can improve the coding efficiency of wavelet, especially when used together with H_Band/V_Band/D_Band Scan. Compared with the raster scan employed in H_Band/V_Band/D_Band Scan previously, the DPCM & Adaptive Scan presented in the invention has 1.7% to 9.7% bit saving for different images, which are table tennis, flower garden, susie, foreman, mother&daughter, carphone and claire.

In any cases where wavelet or subband is applid to code images, it can be found that non-zero coefficients are vertically distributed in horizontal bands, and horizontally distributed in vertical bands. The concept of the invention could be applied to scan these coefficients to make bit use as less as possible no matter what the following coding method, i. e., entropy coding, is. That is to say, a rearrangement process for those coefficients could be done by use of the concept presented in the invention, before any following coding method, such as Huffman VLC, arithm etic coding, vector coding, is used.

The method of the invention becomes more efficient when there are a lot of vertical or horizontal edges in an original image, since it can save a lot of bits in that case, in the same time the coded picture quality would be improved much accordingly.

The concept of the invention is also very useful when we study what is the most efficient scanning method for wavelet coefficients, because it tells us that non-zero coefficients are distributed vertically in horizontal bands, and distributed horizontally in vertical bands, so that we could have a good scanning method to be combined with the idea of the invention.

Claims

1. A video coding method using wavelet with an adaptive scanning method comprising steps of:

    subjecting input video signal to a horizontal and a vertical wavelet decomposition to obtain base, horizontal, vertical and diagonal bands of wavelet coefficients;
    recursively subjecting the resulting base band to further wavelet decomposition to obtain lower layers of base, horizontal, vertical and diagonal bands of wavelet coefficients;
    grouping co-sited coefficients from the different layers of horizontal, vertical and diagonal bands into a plurality of horizontal, vertical and diagonal macro-bands, respectively;
    applying an adaptive quantization to quantize the above coefficients in the said horizontal, vertical and diagonal macro-bands, respectively;
    adaptively scanning and differentially coding the quantized coefficients in the said macro-bands into a plurality of one dimensional arrays, using a technique depending on orientation of the macro-bands and distribution of the coefficients, and
    applying an entropy coding method to code each of the said arrays.

2. A video coding method according to claim 1, wherein

    the grouping of the wavelet coefficients into macro-bands comprises following steps of:

    keeping the lowest band as the Base band, B1b;
    taking one coefficient in the lowest horizontal band, B1h;
    taking 2x2 coefficients in the next lowest horizontal band, B2h;
    taking 4x4 coefficients in the next lowest horizontal band, B3h;
    taking 8x8 coefficients in the next lowest horizontal band, B4h; all at the same spatial position to form one of the horizontal macro-bands;
    in the same manner,
    taking one coefficient in the lowest vertical band, B1v;
    taking 2x2 coefficients in the next lowest vertical band, B2v;
    taking 4x4 coefficients in the next lowest vertical band, B3v;
    taking 8x8 coefficients in the next lowest vertical band, B4v; all at the same spatial position to form one of the vertival macro-bands;
    in the same manner,
    taking one coefficient in the lowest diagonal band, B1d;
    taking 2x2 coefficients in the next lowest diagonal band, B2d;
    taking 4x4 coefficients in the next lowest diagonal band, B3d;
    taking 8x8 coefficients in the next lowest diagonal band, B4d; all at the same spatial position to form one of the diagonal macro-bands;

3. A video coding method according to claim 1 or 2 where the macro-bands are scanned into one dimensional arrays , comprising the following steps of:

    scanning the horizontal macro-band coefficients vertically from the first coefficient to the last in each column, column by column starting from the lowest band to the highest band (B1h to B4h);
    scanning the vertical macro-band coefficients horizontally from the first coefficient to the last coefficient in each row, row by row starting from the lowest band to the highest band (B1v to B4v); and
    scanning the diagonal macro-band coefficients

in zig-zag scan manner starting from the lowest band to the highest band (B1d to B4d).

4. A video coding method according to claim 3 wherein alternatively, the scanning include the following steps of:

   alternating the vertical scan between scanning from the first coefficient to the last coefficient and scanning from the last coefficient to the first coefficient for each of the successive column in the horizontal macro-band; and
   alternating the horizontal scan between scanneng from the first coefficient to the last coefficient and scanning from the last coefficient to the first coefficient for each of the successive row in the vertical macro-band.

5. A video coding method according to claim 1, 2, 3 , or 4, comprising further additional step of

   applying a one dimension differential pulse modulation, DPCM, coding for the coefficients within each of the vertical column and horizontal row of the horizontal and vertical micro-bands, respectively.

6. A video coding method according to claim 1, 2, 3, 4, or 5 whereby
   the scanning is further modified by adaptively scanning the coefficients of the horizontal, vertical, and diagonal macro-bands , comprising following steps of:

   for each horizontal macro-band, horizontally scanning the first column at the beginning of each horizontal band until a non-zero coefficient is found; vertically scanning the remainder of the coefficients in each horizontal band by starting from the next vertical coefficient from the said non-zero coefficient, and wrapping around to the coefficients that have not been scanned before proceeding to the next band;
   in the same manner, for each vertical macro-band, vertically scanning the first row at the beginning for each of vertical band until a non-zero coefficient is found; horizontally scanning the remainder of the coefficients in each vertical band by starting from the next horizontal coefficient from the said non-zero coefficient, and wrapping around to the coefficients that have not been scanned before proceeding to the next band; and
   for each diagonal macro-band,applying a normal zig-zag scan or a raster scan to obtain the said one dimensional arrays.

7. A video coding method using wavelet according to claim 1, 2, 3, 4, 5 or 6, further comprising the steps of;

   applying run length Huffman like coding to the said one dimensional arrays obtained in claims 1, 2, 3, 4, 5 or 6, to give the coded bits;
   including the coded bits into a bitstream, and sending the bitstream to a decoder.

8. A video coding method according to claim 1, 2, 3, 4, 5, 6 or 7 wherein
   the wavelet decomposition is replaced by a general subband decomposition technique.

9. A video decoding method comprising steps of:

   decoding the coded bits using the Huffman-like run legth decoding into one dimensional arrays;
   forming the macro-bands from the said one dimensional arrays by inverse scanning the one dimensional array into macro bands according to the order in the claim 3, 4, 5 or 6;
   inverse quantization of the levels in the said macro-bands to form the wavelet coefficients;
   reconstructing the horizontal, vertical and diagonal bands from the said macro-bands, and
   recursively applying a horizontal and a vertical wavelet reconstruction to the wavelet bands to form the reconstructed image.

10. A video decoding method according to claim 9 wherein
   the wavelet synthesis is replaced by a gereral subband reconstruction technique.

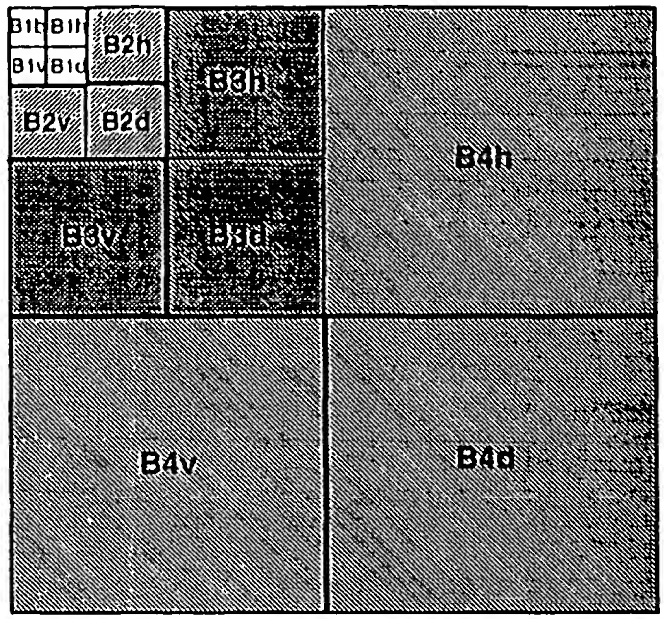

Figure 1 Wavelet Decomposition with 13 Bands

Figure 2 One Layer of Wavelet Decomposition for Carphone

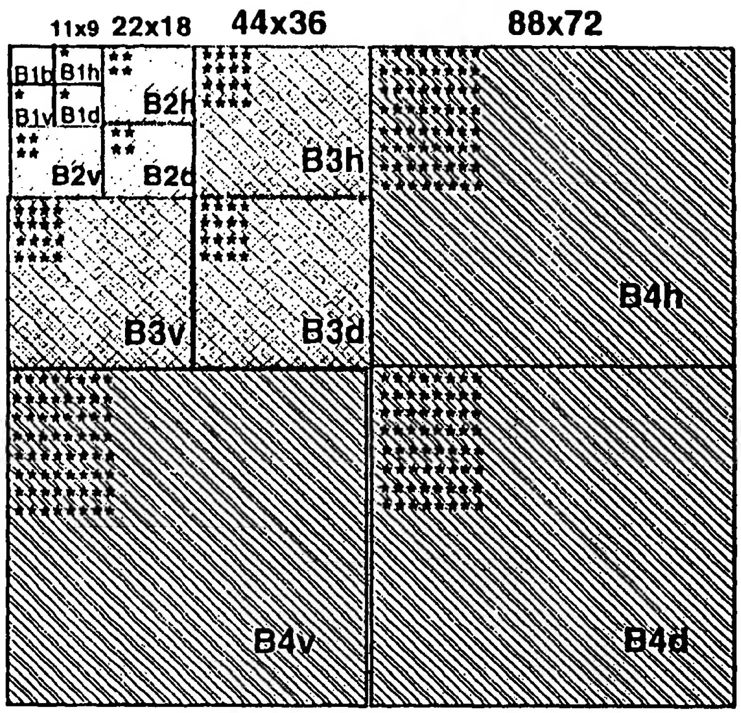

Figure 3 Illustration for H_Band/V_Band/D_Band Scan

Horizontal Macro Band

22							
-12	3						
-6	1						
0	2	-6	2				
0	2	-6	2				
0	2	-6	2				
0	2	-5	1				
0	0	0	0	0	0	-3	1
0	0	0	0	0	0	-3	1
0	0	0	0	0	0	-3	1
0	0	0	0	0	0	-3	1
0	0	0	0	0	0	-3	1
0	0	0	0	0	0	-3	1
0	0	0	0	0	0	-3	1
0	0	0	0	0	0	-3	1

Vertical Macro Band

18							
11	10						
-3	0						
-3	-3	-3	-3				
1	1	1	1				
1	2	3	4				
-3	-3	-3	-3				
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
-1	-1	-1	-1	-1	-1	-1	-1
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
-1	-1	-1	0	0	0	0	0
0	0	0	0	0	0	0	0

Diagonal Macro Band

9							
1	0						
0	0						
-4	3	-1	0				
1	-1	0	0				
-1	0	0	0				
0	-1	1	0				
0	0	0	0	0	0	0	0
0	0	0	0	0	0	1	-1
0	0	1	0	0	0	0	0
0	0	0	1	-1	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

Figure 4 Examples of Three Macro Bands for Carphone Sequence

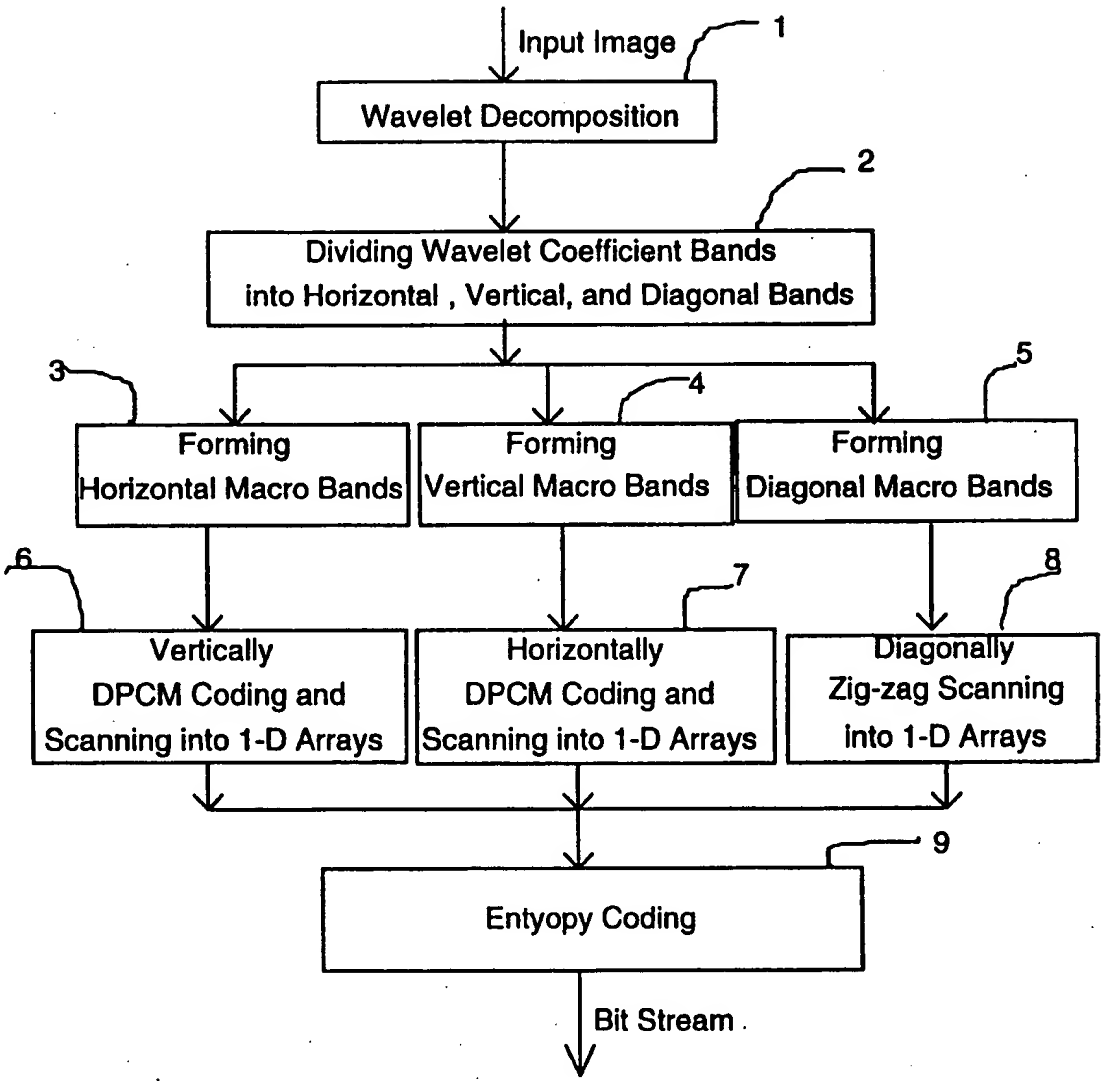

Figure 5 General Diagram for H_Band/V_Band/D_Band Scan

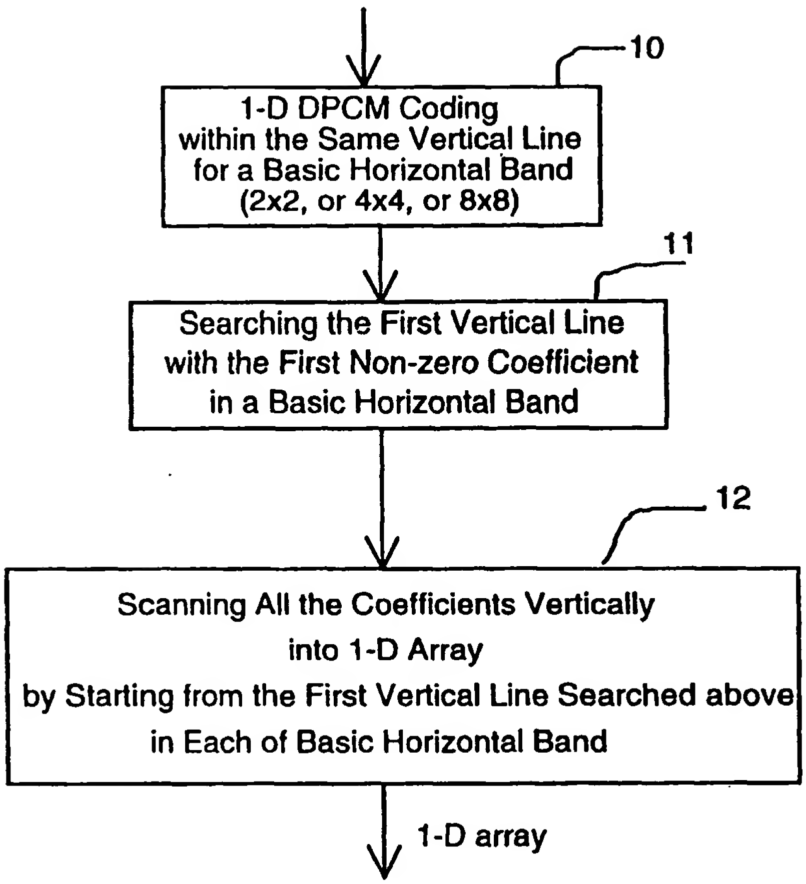

Figure 6 1-D DPCM & Adaptive Scanning for a Horizontal Macro Band

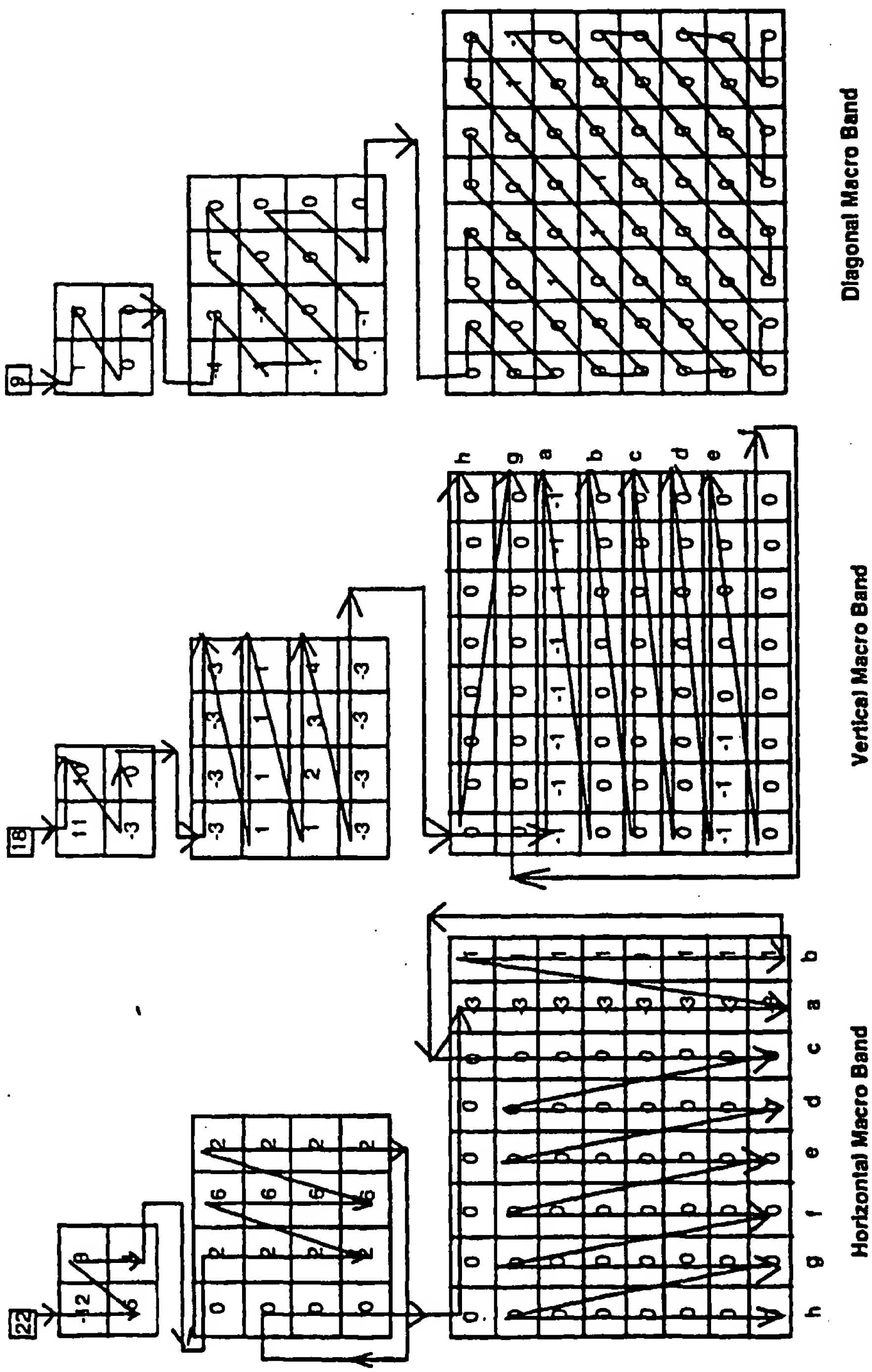

Figure 7(a) Forward Adaptive Scan

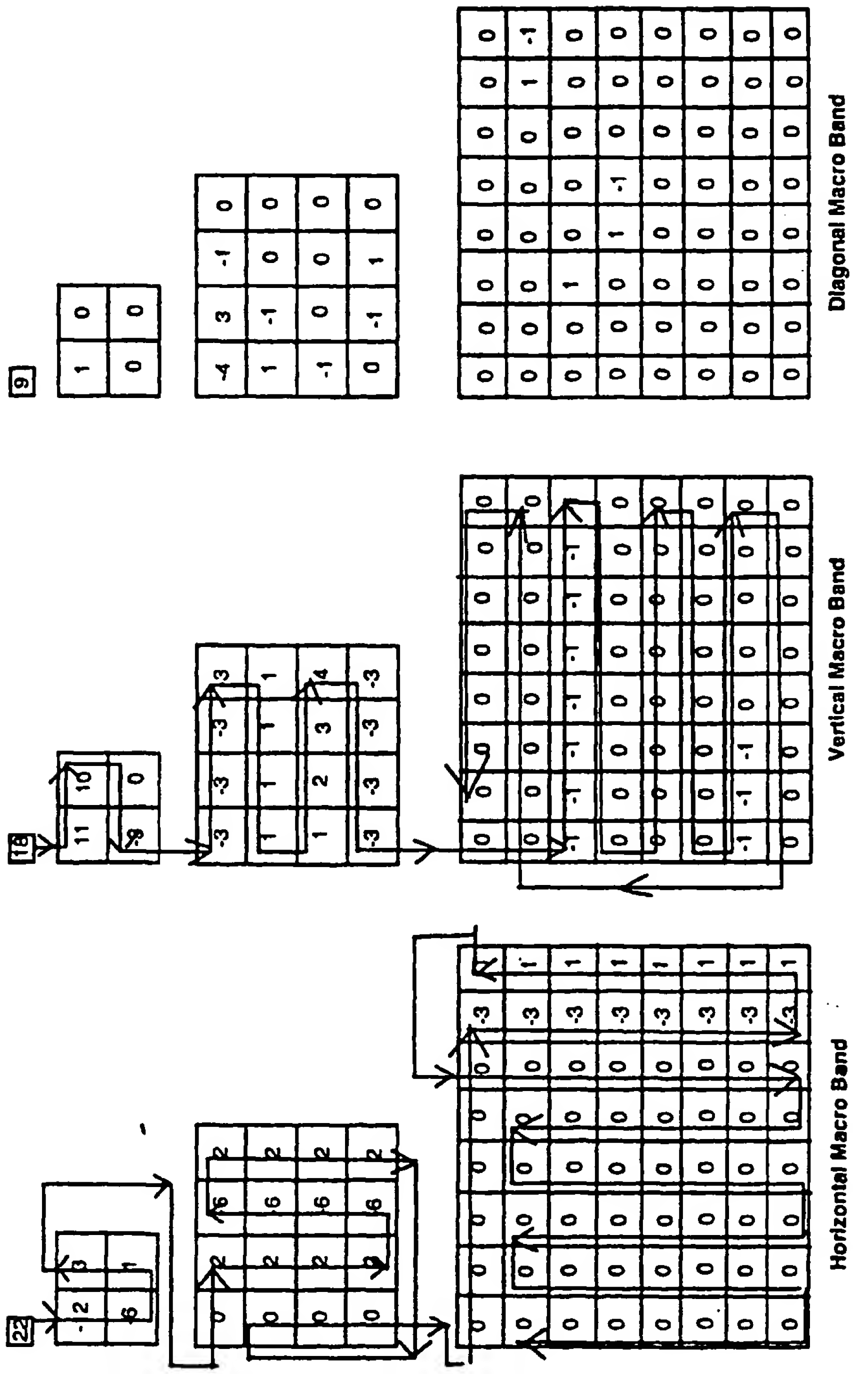

Figure 7(b) Continuous Adaptive Scan

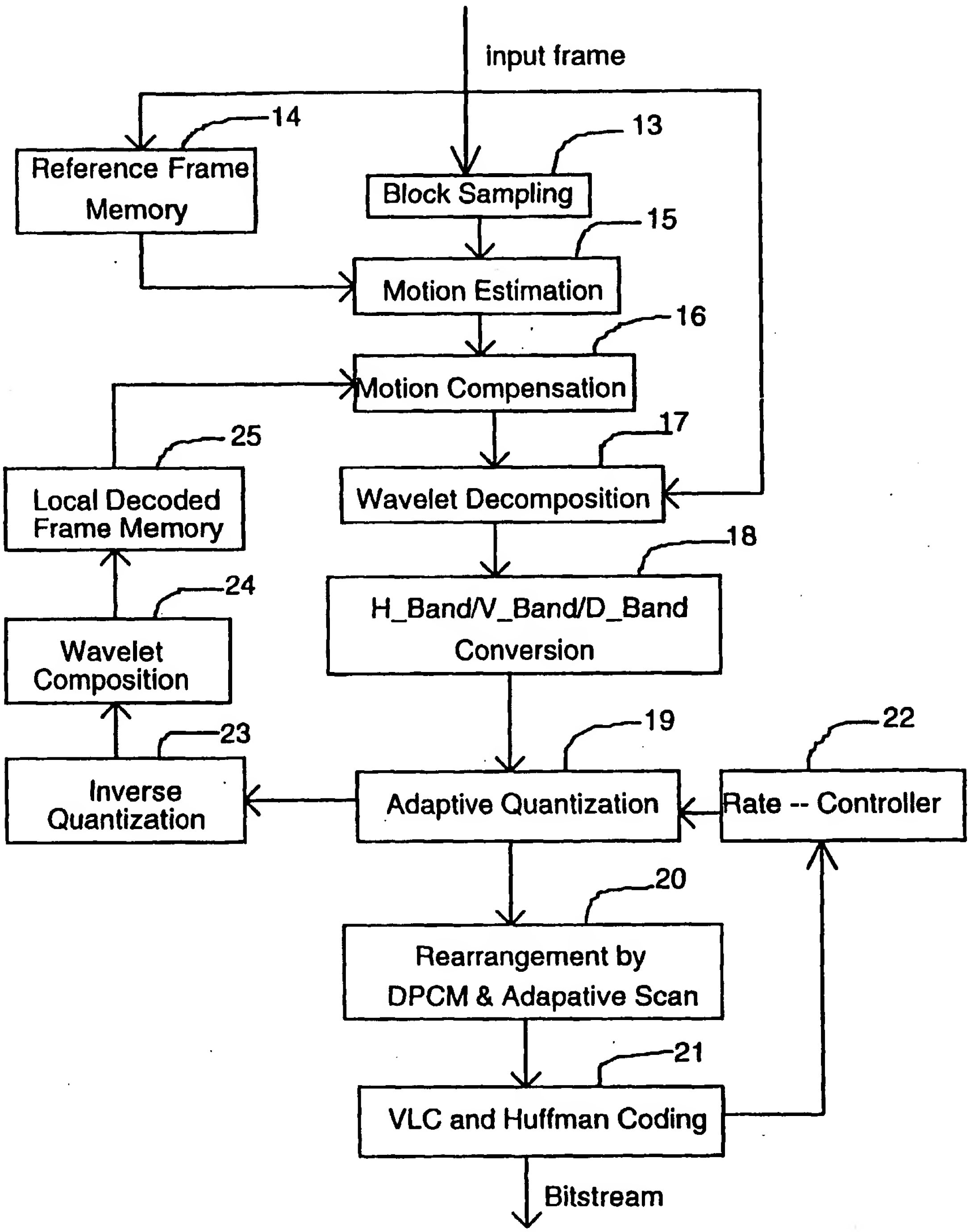

Figure 8 An Encoder of HVDS with DPCM & Adaptive Scan